



Morehead State University 21 meter Antenna Upgrade to DSN Compatibility

IND CubeSat Communications Briefing and Technical Interchange

November 10, 2015

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MOREHEAD STATE UNIVERSITY



Jet Propulsion Laboratory
California Institute of Technology

Where Is Morehead State University?

Morehead, KY 40351

Untitled Placemark

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

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38°15'22.96" N 83°22'44.19" W elev 722 ft

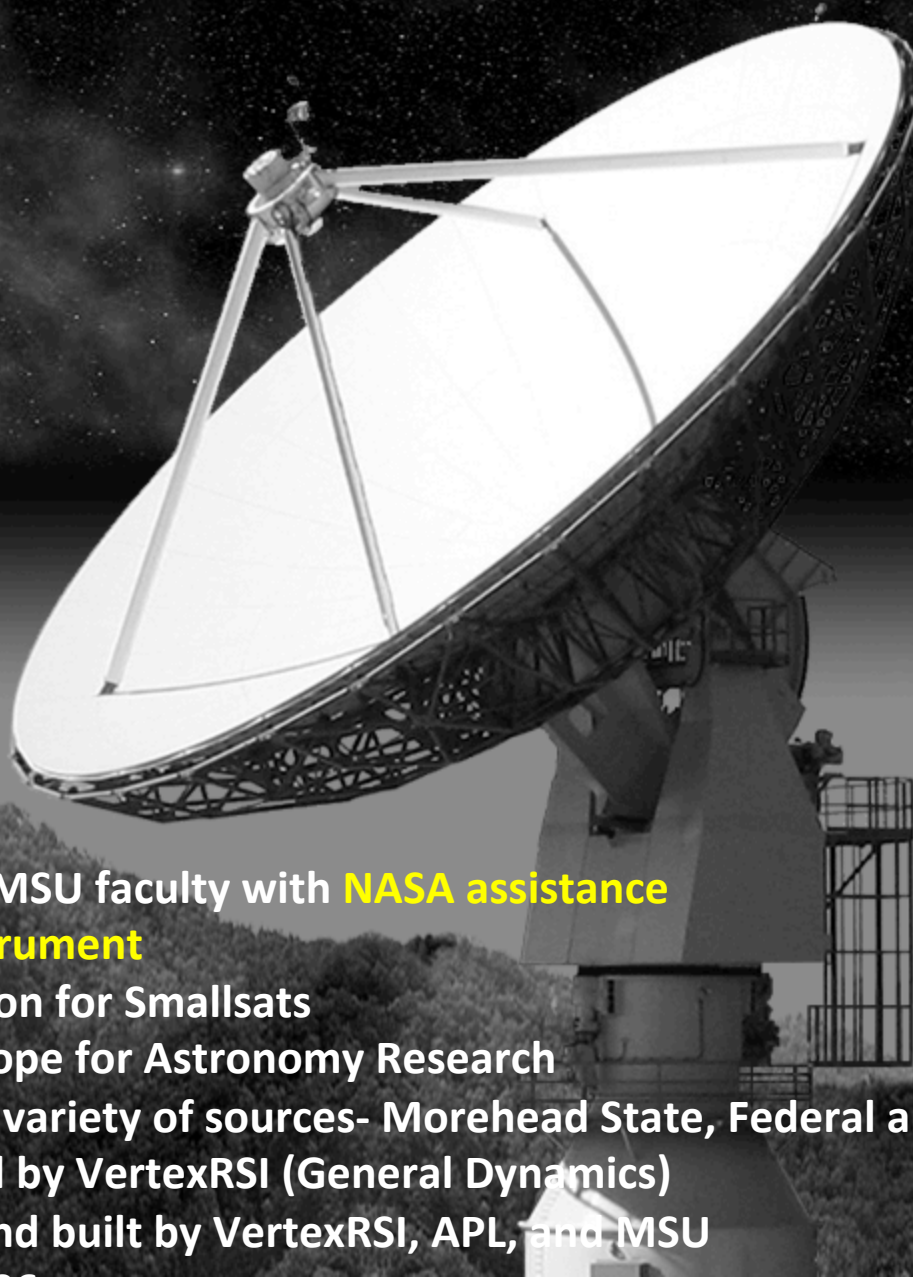
Eye alt 3297.19 mi

©2009 Google



Quiet RFI Environment in Eastern Kentucky (Southeastern US)

21 Meter System



- Specifications by MSU faculty with **NASA assistance**
- **Dual Purpose Instrument**
 - Ground Station for Smallsats
 - Radio Telescope for Astronomy Research
- Funded \$3.4 M -a variety of sources- Morehead State, Federal and State Funds, KSTC, NASA
- Built and Installed by VertexRSI (General Dynamics)
- Feeds Designed and built by VertexRSI, APL, and MSU

Space Projects Create Opportunities for Students



- Undergraduate Research Experiences
- Instrumentation Experience
- Engineering Design
- Observational Astrophysics Research
- Ground Ops (TT&C)
- Project Management Experience
- Systems-level Engineering Experience

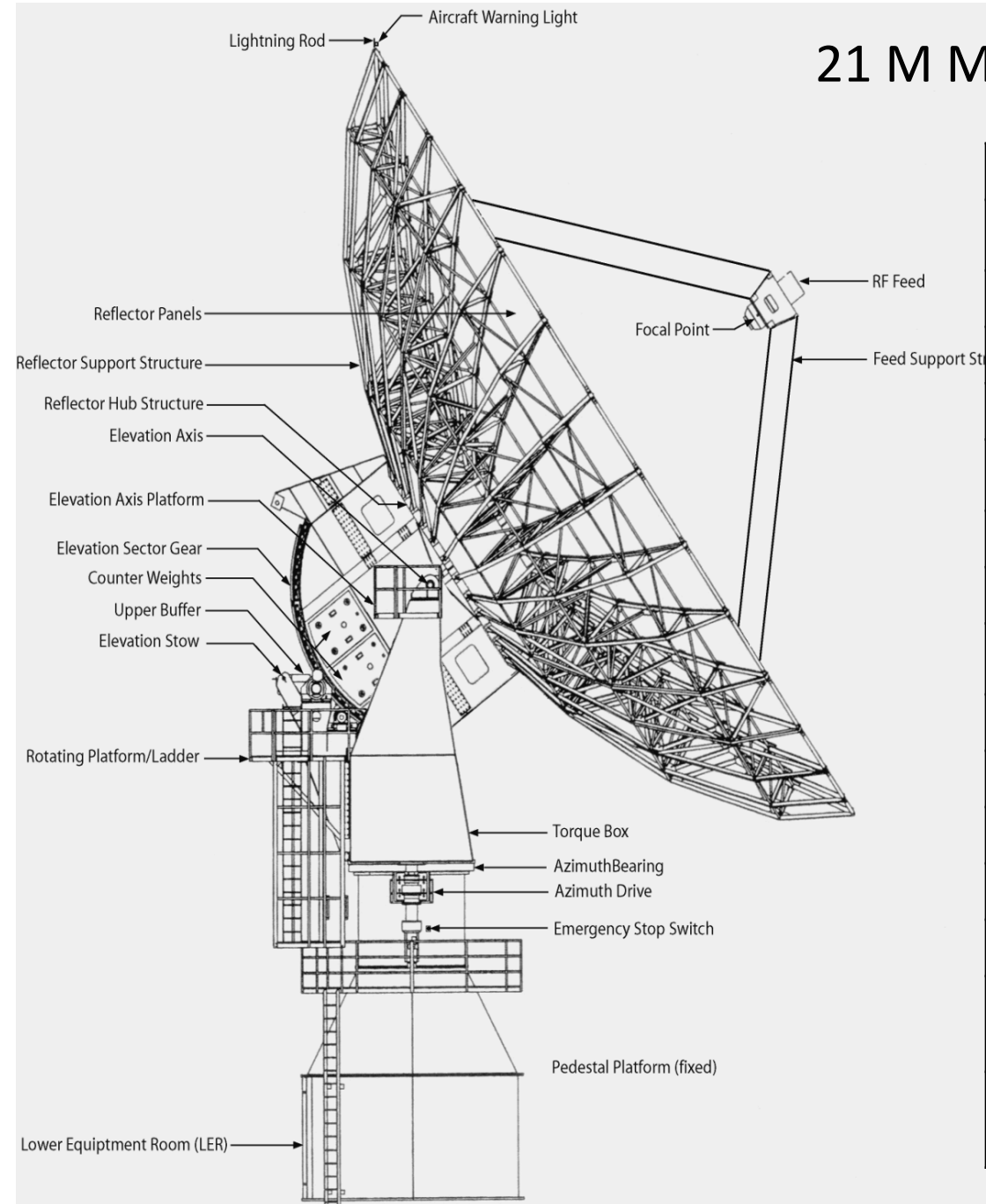


21 M Operations

- Radio Telescope Mode for Research in Astrophysics
- Satellite Ground Station for Ground Ops/Mission Support
- Test-Bed for Experimental Communication Systems for Small Satellite Systems



21 M Mechanical/Dynamical Systems



Parameter	Measured Values
Axis Slew Velocity	
Azimuth	> 3.0 °/sec minimum
Elevation	> 1.6 °/sec minimum
Polarization	> 0.7 °/sec minimum
Axis Acceleration	
Azimuth	1.0 °/sec²
Elevation	0.6 °/sec²
Travel Range	
Azimuth	± 269.8°
Elevation	1.0° to 90.3°
Polarization	± 90.9°
Pointing Accuracy	0.005° RMS
Tracking Accuracy	0.0004° RMS
Aperture Efficiency, η (L/Ku)	0.653/0.563
Surface Tolerance @ 35 mph wind	< 0.020" RMS

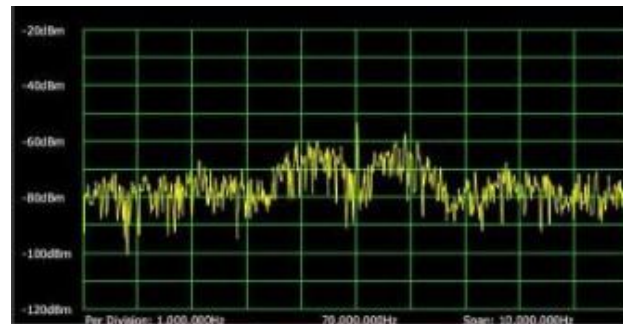
2012 Station Upgrade



TIMED Spacecraft FFT

- Major Upgrade Supported by NASA HEOMD and Johns Hopkins APL, included:

- Full Remote Control of All Systems
- All equipment required to process spacecraft data
- Timing and frequency references
- Uplink capability implemented
- SLE Compliance
- NASA NEN Compatible
- IOAG Compatible
- Software-Defined TT&C Processor (SoftFEP)
- T400 Modem
- High Data Rate Digitizer for Experimental Missions



Interplanetary SmallSat Ground Ops: Morehead State 21 M Ground Station- **Current State**

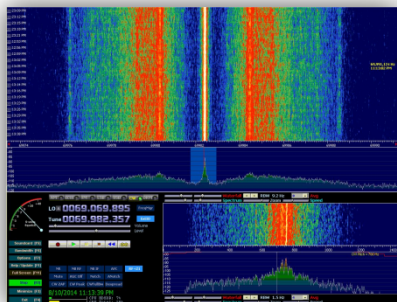


Morehead State University
21 M Ground Station

- Fully Operational, Full-Motion, 21 M Antenna
- Operational Experience: LRO, ISEE-3, Planet Labs, KySpace
- High Gain, Pointing and Tracking Accuracy
- Station is ideal for Inner Solar System Experiments
- Full Remote Control of All Systems
- X-Band Downlink Currently- Uplink capability planned
- NASA NEN Compatible
- Software-Defined TT&C Processor (SoftFEP) and High Data Rate Digitizer for Experimental Missions
- Extensive use of Student Operators (STEM Engagement)
- Plans for DSN Compatibility Upgrades with JPL assistance



Student Operators in the MSU 21 M LER



ISEE-3 Carrier During Lunar Fly-by Sept 2014



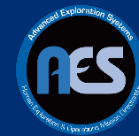
Student Operators in the MSU Mission Ops Center

MSU 21 Meter Current RF Capabilities

Radio Band	Frequency Range	Gain	Uses of Band
UHF	400-480 MHz	30 dBi	Satellite Telecom
S-Band	2.2-2.5 GHz	52.8 dBi	Both Satellite Telecom and Radio Astronomy
X-Band	7.0-7.8 GHz	62.0 dBi	Primarily Satellite Telecom
Ku-Band	11.2-12.7 GHz	65.50 dBi	Primarily Satellite Telecom



Morehead State University 21m Upgrade to DSN Compatibility



Goldstone, California



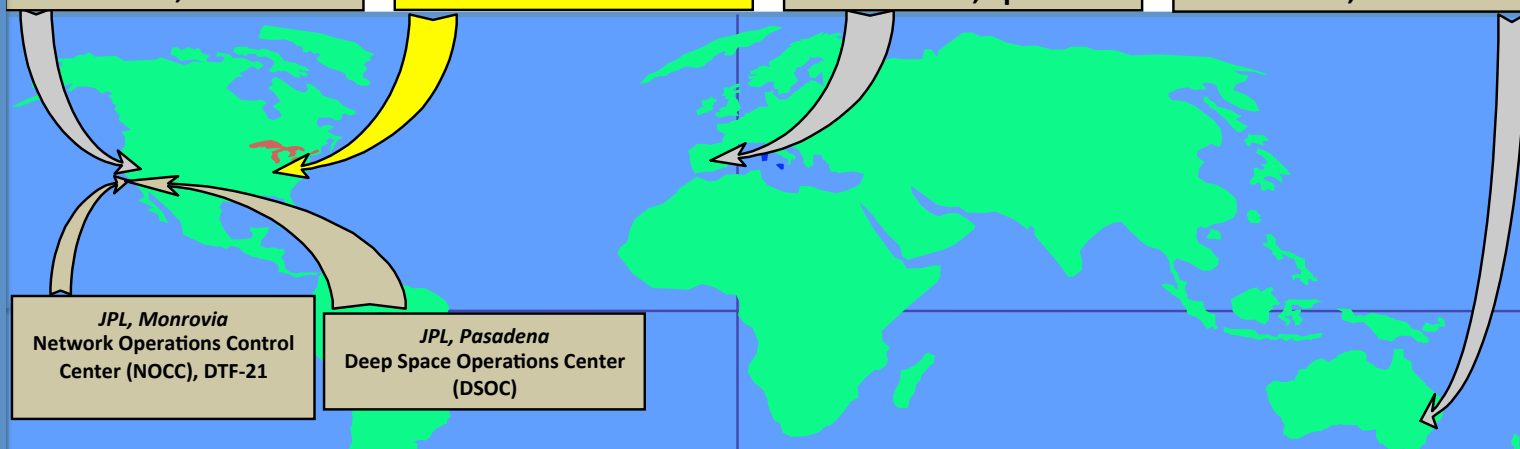
Morehead State Univ.



Madrid, Spain



Canberra, Australia



JPL, Monrovia
Network Operations Control
Center (NOCC), DTF-21

JPL, Pasadena
Deep Space Operations Center
(DSOC)

Objective:

- Demonstrate a cost-effective process for expanding DSN capabilities by utilizing non-NASA assets to provide communication and navigation services to small spacecraft missions to the Moon and inner solar system, thereby enabling interplanetary research with small spacecraft platforms.

Benefits:

- Serves as a test-case to define a path for other non-NASA ground stations to provide auxiliary deep space navigation and tracking support for small spacecraft missions.
- Develops an operational capability to support EM-1 Cubesat missions in the 2018 timeframe

Technical Approach:

- Develop and implement a strategy to transfer Deep Space Network (DSN) processes and protocols to the MSU 21 m antenna system and to upgrade the antenna hardware and software systems to enable integration into the DSN as an auxiliary station to support small spacecraft missions.
- The project is focused on the implementation of deep space communications, tracking and navigation techniques as well as adoption of CCSDS data interface standards such as the Space-link Extension service.
- Implement systems upgrades, conduct tests/demonstrations, and transition to an operational capability.

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MSU 21m Telescope Upgrade Summary

Technical Area	Description
System Engineering, Design, and Testing	(1) Requirements specification, (2) Cross-system interface agreements and technical documentation, (3) Design, Configure, Implement, Test and Validate Hardware and Software upgrades required for DSN compatibility, interoperability, and tracking and commanding capabilities, (4) Test plans and procedures, Validation of demonstration results, (5) Performance analysis
Telemetry Interoperability	Implement Telemetry SLE for maximum interoperability. Identify changes needed on the DSN flow data to mission users.
Tracking Interoperability	Implement tracking capability - including ranging/Doppler processing and transmitter. Identify changes needed within the DSN to produce the data flow to mission users. Implement capabilities and data items needed at MSU to provide tracking calibration data (e.g., antenna position, earth orientation, media calibration, UTC and frequency time offset)
Command Interoperability	Implement Command SLE. Identify changes needed on the DSN to realize the data flow from mission users to MSU.
Service Management interoperability	Define and implement the interface between DSN and MSU for service schedule and provision of support data (ephemeris, frequency prediction, spacecraft sequence of event, monitor data to mission users)
Configuration Management	Establish guidelines on a minimally needed Configuration Management (CM) process controls to maximize service availability. Develop and implement a plan for achieving the required level of CM. Includes site security.

FY15

Planning, Systems Engineering

FY16

Systems Upgrades, Implementation

FY17

Downlink and Uplink Experiments

FY18

Navigation Experiments/Transition to Mission Support

FY19

Operational Capability



Expected 21m Performance



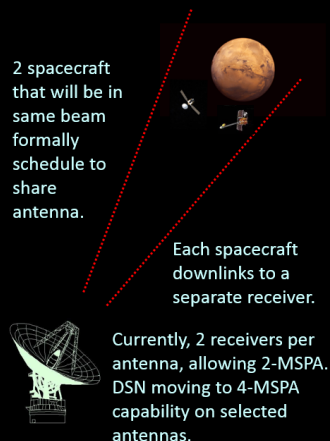
Performance Measure	Current Values	Post-Upgraded Targets
X-Band Frequency Range	7.0 – 7.8 GHz	7.0 – 8.5 GHz
LNA Temperature	70 K	< 20 K
System Temperature T_{sys}	215 K	<100 K
Antenna Gain	62.0 dBi (@7.7 GHz)	62.7 dBi (@8.4 GHz)
System Noise Spectral Density	-175 dBm/Hz	<-178 dBm/Hz
G/T at 5° Elevation	37.5 dBi/K	40.4 dBi/K
Time Standard	GPS (40-ns)	Cesium (2ns/day)
SLE Compliant	No	Yes
CCSDS Capable	No	Yes



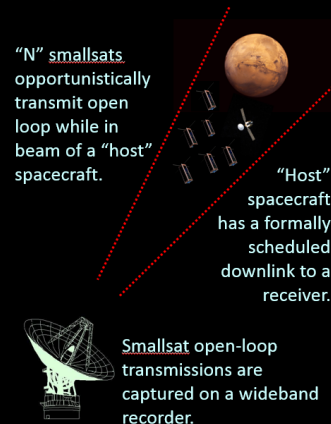
Possible Extensions and Adaptations

- Multiple Spacecraft per Aperture (MSPA) and Opportunistic MSPA
- Delay/Disruption Tolerant Networking

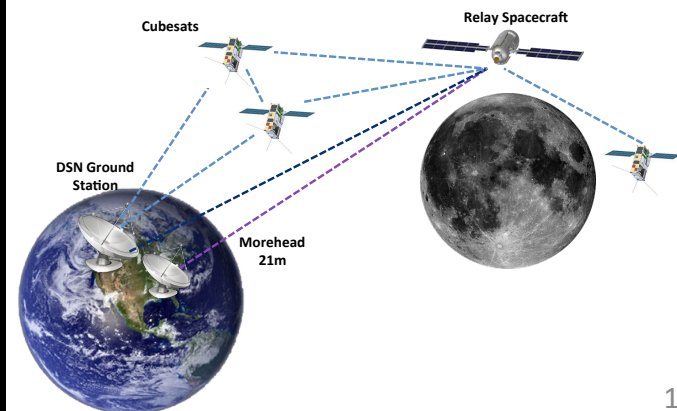
Traditional MSPA



Opportunistic MSPA



Support for Space Networking



Backup Material

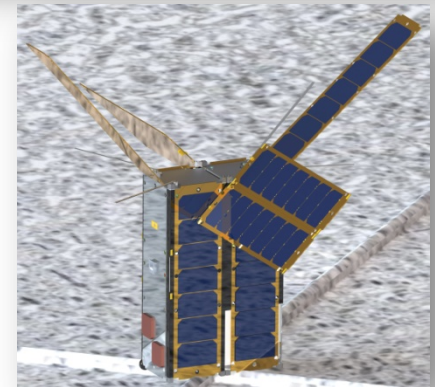
21 M Ground Station Mission Support

Support SmallSats Missions in:

- LEO
- MEO
- GEO
- Lunar
- Near-by Asteroids
- Approaching Comets

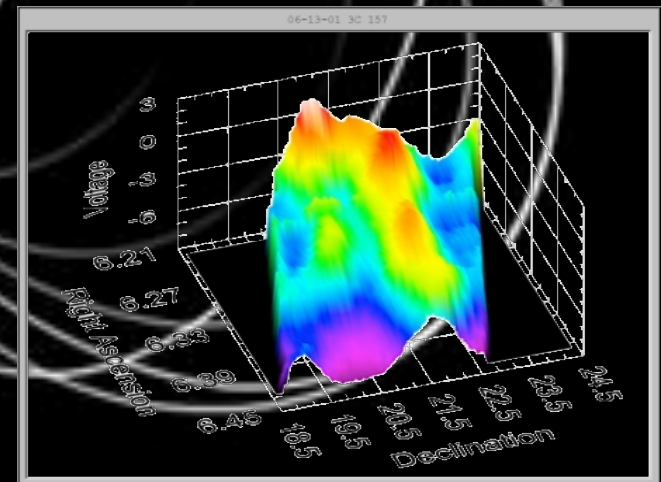
Missions Operations For:

- Planet Labs Dove Constellation
- LRO (Mini-RF Comms)
- ISEE-3 Reboot
- CubeSats and MicroSats:
 - CXBN, KySat-2, Firefly, T-LogoQube, Eagle-2, UniSat-5, EduSat, UniSat-6, SERPENS



Research in Astrophysics

- SNR Research
- AGN Research
- GRB Research
- Galaxy Dynamics
- Instrumentation Development
- Pulsar Timing



Research Has let to the Discovery of Two Millisecond Pulsars by Pre-College Students

- J1820+0159
Discovered on
1. 20. 2011 by H. Mabry
- J1400-1410
Discovered on on
1.13.2012 by J. Pal
- Using Archival GBT
Data
- Follow-on Observations
Made with 21 M

